Omega Laser Facility and Diagnostic Timing Management

E. M. HILL and J. C. PUTH
University of Rochester, Laboratory for Laser Energetics

Overview of Omega-60 on-shot timing and nominal setup conditions
- Timing is configured for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- On-shot timing as predicted by the UV timing diagnostics is within 100 ps of the SRF requested timing.
- Timing errors can be lightened up in the UV at the request of the PI.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is adjusted by changing the timing at the front-end timing diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

T0 is the nominal system timing for the Omega Laser Facility
- T0 (Target) is the theoretical time when all laser pulses arrive at target chamber center (TCC) if no delay is applied.
- All shot request form (SRF) timing delays and diagnostic timing delays are applied with respect to T0.
- Most diagnostics use the fiducial laser to reference timing with respect to T0.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

The Omega Laser Facility continues to build capabilities to achieve the desired experimental beam-to-beam timing and accurately capture the target event on diagnostics.
- Diagnostics predict the timing before the shot.
- Target diagnostics can be used to measure beam-to-beam timing under appropriate conditions.

Diagnose of OMEGA EP timing can be improved after the first shot of the day.
- These laser diagnostic predict T0 on-target timing based on historical calibration.

OMEGA EP timing is moved by individual beamline and measured by a suite of diagnostics
- Beam-to-beam timing is adjusted by changing the timing of the entire laser system (seed laser and all active beamlines).
- Timing adjustments in long-pulse mode are relatively straightforward.
- Timing adjustments in short-pulse mode may take up to 30 min; this will not cause shot delays if timing changes are requested within 30 min post-shot.
- All beam-to-beam timing uses Beamline 2 as the reference.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.

Methods to change and measure OMEGA-60 beam-to-beam timing are well understood
- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays.
- PLAS delays can be applied to any individual beam.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

OMEGA EP timing can be improved after the first shot of the day
- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- Beam-to-beam timing is checked twice a day.
- SLD and backlighters can be adjusted using path-length adjustment diagnostic and upon PI request.

The target diagnostic timing manager (TDTM) will be available in FY14
- TDTM is an upcoming software package to coordinate control of timing and feedback from pre-shot timing checks to ensure that the diagnostic is triggered per the SRF request.
- This software takes into account the standoff distance from TCC, current TIM, conditions, the diagnostic configuration, and the desired timing relative to T0.
- Daily adjustments might be required because of system drift.
Summary

LLE is committed to achieving the highest-quality timing

The Omega Laser Facility continues to build capabilities to achieve the desired experimental beam-to-beam timing and accurately capture the target event on diagnostics.

Diagnostics predict the timing before the shot.

Target diagnostics can be used to measure beam-to-beam timing under appropriate conditions.

The presented results indicate the currently achievable timing.

The Principal Investigator (PI) can work with the shot crew to ensure that the timing feedback is correctly incorporated to achieve the desired result by separating observed errors and new desired timing requests.
Laser and target diagnostics are used to time the OMEGA-60 and OMEGA EP Laser Systems

- Timing of the OMEGA-60 and OMEGA EP Laser Systems relies on multiple pre-shot and on-shot laser predictive diagnostics
- These laser diagnostics predict T-0 on-target timing based on historical calibration from on-shot target diagnostics
- To determine on-shot timing, a target timing diagnostic must be used

GCC: grating compressor chamber
FCC: frequency-conversion crystals
T-0 is the nominal system timing for the Omega Laser Facility

• T-0 (Tzero) is the theoretical time when all laser pulses arrive at target chamber center (TCC) if no delay is applied
  – All shot request form (SRF) timing delays and diagnostic timing delays are applied with respect to T-0

• Most diagnostics use the fiducial laser to reference timing with respect to T-0
Methods to change and measure OMEGA-60 beam-to-beam timing are well understood

- Beam-to-beam timing is adjusted using path-length adjustment system (PLAS) delays
  - PLAS delays can be applied to any individual beam
  - beam-to-beam timing is checked twice a year
  - the PLAS delay error is <10 ps over the full range

- When using both the smoothing by spectral dispersion (SSD) and backlighter drivers, driver-to-driver timing is adjusted by changing the timing of the driver

<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>Location</th>
<th>Capture Time</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast scope</td>
<td>Front end</td>
<td>Pre-shot</td>
<td>Front end drivers—E. Hill</td>
</tr>
<tr>
<td>P510(s)</td>
<td>UV</td>
<td>On-shot</td>
<td>Beamlines—R. Dean</td>
</tr>
<tr>
<td>NTD</td>
<td>Target chamber—fixed</td>
<td>On-shot</td>
<td>Neutronics—C. Stoeckl</td>
</tr>
<tr>
<td>PJX</td>
<td>Target chamber—TIM</td>
<td>On-shot</td>
<td>Neutronics—C. Stoeckl</td>
</tr>
<tr>
<td>UFXRSC</td>
<td>Target chamber—TIM</td>
<td>On-shot</td>
<td>Neutronics—C. Stoeckl</td>
</tr>
</tbody>
</table>

NTD: neutron temporal diagnostic
UFXRSC: ultrafast x-ray streak camera
OMEGA EP timing is moved by individual beamline and measured by a suite of diagnostics

- Beam-to-beam timing is adjusted by changing the timing of the entire laser system (seed laser and all active beamline components)
- Timing adjustments in long-pulse mode are relatively straightforward
- Timing adjustments in short-pulse mode may take up to 30 min; this will not cause shot delays if timing changes are requested within 30 min post-shot
- All beam-to-beam timing uses Beamline 2 as the reference

<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>Location</th>
<th>Capture Time</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast scope</td>
<td>Front end</td>
<td>Pre-shot</td>
<td>Front sources—E. Hill</td>
</tr>
<tr>
<td>UV ROSS</td>
<td>UV</td>
<td>On-shot</td>
<td>Front sources—E. Hill</td>
</tr>
<tr>
<td>SPDP PSM</td>
<td>SPDP</td>
<td>Pre-shot/On-shot</td>
<td>Front-end sources—E. Hill</td>
</tr>
<tr>
<td>PJX</td>
<td>Target chamber—TIM</td>
<td>On-shot</td>
<td>Neutronics—C. Stoeckl</td>
</tr>
<tr>
<td>UFXRSC</td>
<td>Target chamber—TIM</td>
<td>On-shot</td>
<td>Neutronics—C. Stoeckl</td>
</tr>
</tbody>
</table>

UV ROSS: Ultra violet Rochester Optical Streak System
SPDP PSM: short pulse diagnostic package pulse shape measurement
TIM: ten-inch manipulator
Overview of OMEGA-60 on-shot timing and nominal setup conditions

- Timing is configured for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 50 ps of the SRF.
- On-shot timing as predicted by the UV timing diagnostics is within 100 ps of the SRF requested timing.
- Timing errors can be tightened up in the UV at the request of the PI.

<table>
<thead>
<tr>
<th></th>
<th>T-0 (average)</th>
<th>STD</th>
<th>Diagnostic</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD</td>
<td>20 ps</td>
<td>10 ps</td>
<td>P510</td>
</tr>
<tr>
<td>SSD to backlighter</td>
<td>120 ps</td>
<td>50 ps</td>
<td>P510</td>
</tr>
<tr>
<td>SSD to OMEGA EP</td>
<td>40 ps</td>
<td>40 ps</td>
<td>NTD</td>
</tr>
</tbody>
</table>
OMEGA EP timing can be improved after the first shot of the day

- Timing is set up for the first shot of that day such that the predicted timing at the front-end timing diagnostic is within 100 ps of the SRF request unless tighter timing is required.

- On-shot timing as predicted by the UV timing diagnostics is within 100 ps of the SRF requested timing on the first shot of the day.

- Timing errors can be reduced up if data is available from a target timing diagnostic and upon PI request.

<table>
<thead>
<tr>
<th>First shot of day</th>
<th>Subsequent shots</th>
<th>Critical timing</th>
<th>Diagnostic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-0 (average)</td>
<td>T-0 (average)</td>
<td>T-0 (average)</td>
</tr>
<tr>
<td></td>
<td>STD</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>SP beam to beam*</td>
<td></td>
<td>10 ps</td>
<td>10 ps</td>
</tr>
<tr>
<td></td>
<td>10 ps</td>
<td>30 ps</td>
<td>20 ps</td>
</tr>
<tr>
<td>LP beam to beam*</td>
<td>20 ps</td>
<td>75 ps</td>
<td>UV ROSS</td>
</tr>
<tr>
<td></td>
<td>75 ps</td>
<td>75 ps</td>
<td></td>
</tr>
</tbody>
</table>

STD: standard deviation
*Beam-to-beam timing is reported with respect to Beamline 2.
The target diagnostic timing manager (TDTM) will be available in FY14

- TDTM is an upcoming software package to centralize control of timing and feedback from pre-shot timing checks to ensure that the diagnostics are triggered per the SRF request

- This software will take into account the standoff distance from TCC, current TIM conditions, the diagnostic configuration, and the desired timing relative to T-0

- In pre-shot, the timing scope is utilized to compare a characteristic signal from the target diagnostic to the fiducial laser pulse

- Corrections are applied to the trigger timing to ensure the diagnostic captures the shot event
TDTM will replace spreadsheet-based timing configuration

- Historical characterization of the diagnostic will be tracked and accounted for in diagnostic setup
  - new diagnostics will require additional effort to characterize and may require calibration target shots
  - when diagnostics are modified, characterization of changes will be required to achieve desired results on the first shot
- Daily adjustments might be required because of system drift
PI specifies
- laser-timing parameters
- the diagnostic acquisition start time

ESO sets up diagnostic timing to match SRF

Sources/Drivers Operator sets up timing per SRF

Target Shot

Analyze target diagnostic for beam timing information

Analyze laser-diagnostic prediction for beam-timing information

How do laser-timing changes affect the diagnostic

Did the acquisition start time match the intent of the shot

If error is significant to shot series: alert the ESO who will apply a PI offset to the following shot

Is there a change in the desired acquisition start time for the next shot

YES

SD modifies SRF

NO

ESO modifies SRF

If error is significant to shot series: alert the ESO who will apply a PI offset to the following shot

Is there a change in the desired beam timing for the next shot

YES

NO

If error is significant to shot series: alert the Shot Director who will apply a correction offset to the following shot

Did the actual timing of the shot match the desired timing of the SRF to within specification

YES

NO

ESO: experimental system operator

SD: shot director